ART. XVIII.—*Geological Notes on the River Yarra Improvement Sections at the Botanical Gardens and vicinity, Melbourne.*

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(With Plates XLI. and XLII.)

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The notes incorporated in the following paper were made in the year 1898, during the time work was in progress straightening the course of the river Yarra, between Brander's Ferry and Cremorne Street, Richmond. The work was carried out by the Public Works Department on the recommendation of the Floods Prevention Board to prevent the flooding of the low-lying portions of Richmond and South Yarra during heavy rains in the Yarra basin. It was originally intended to carry the works up to the Cremorne Railway Bridge, and it was the hope that the section on the northern side of the river would reveal the relation of the basalt to the shell-bearing marls showing in the cuttings that caused the delay in bringing these notes before the Society. The excavation on the northern side of the river near the Friendly Societies' Gardens did not, as far as noticed by me, afford sufficient evidence regarding this relation, but as the extension of the works referred to has been suspended by the Government there is nothing to be gained by further delay.

The accompanying map of the locality under review, is based upon the contour map of Melbourne and suburbs published by the Department of Lands and Survey, with the Yarra improvements, geological and other information added. The area is embraced in Quarter Sheet No. 1 of the Geological Survey.

The country may be seen from the map to comprise the narrow valley of the Yarra and the bordering Silurian ridges. These ridges are rather steep on the southern side, but rise gently on the northern except near Prince's Bridge where they are much steeper. The southern ridge is covered by the remnant of a

Tertiary series of rocks consisting of gravels, sands, clays, and sandy and ferruginous clays, formerly regarded as of Pliocene, but now as either of Miocene or Eocene age. In the index to the plan I have referred to these beds as Older Tertiary. They form portion of a series of beds that extends across a large part of the Mornington Peninsula and South Gippsland. For almost the whole distance through the locality the river runs near the southern bank by reason of a narrow strip of basalt that occupies the valley. This flow of basalt has apparently filled up the original course of the river and has caused it to impinge against the steep Silurian banks on the south. Probably the basalt reached the foot of these cliffs and necessitated the river having to cut its way through it. But, as the sedimentary rocks would under these circumstances be the more easily eroded the new channel would be formed on the Silurian side, thus accounting for the fact of basalt occurring only in one small patch on the south side of the river.

From Queen's Bridge, which is about 30 chains below Prince's Bridge, the western limit of the map, to past the City of Richmond quarries, some 25 chains above the eastern limit, basalt may be seen in or near the northern bank of the stream for nearly the whole distance. At only one spot, however, as already stated, near the Botanical Bridge, is it noticeable in the south bank.

It appears at the surface either as rounded masses of a few feet in area, as large loose fragments, or under a varying thickness of alluvium as disclosed by shafts and other artificial sections. It is a rather coarse variety and chiefly vesicular and amygdaloidal. The cavities contain the common globular calcite, though in the quarries at Richmond, where there is a thickness of close on 100 feet of this rock, there occur in addition ferrocalcite, aragonite, and various zeolites, such as phacolite, phillipsite, herschelite, and mesolite. Field geology, and the numerous shafts put down by the Metropolitan Board of Works during the last three years in Richmond and Jolimont, in connection with the sewering of the metropolis, show that the basalt extends considerably to the north of Swan Street, Richmond, past the Richmond and Melbourne Cricket Grounds along the edge of the Silurian that embraces most of Yarra Park, round the foot of Jolimont Street,

and up Jolimont Road a little towards Wellington Parade, then, swinging past the front of the East Melbourne Cricket Ground runs parallel with and a little to the south of Flinders Street, past Prince's and Queen's Bridges to the Steam Ferry, Spencer Street. This last record is given in a paper by Mr. Lucas, M.A., B.Sc., F.G.S., "On the Sections of the Delta of the Yarra, displayed in the Fishermen's Bend Cutting."[1]

In the Richmond quarries, where the basalt appears to consist of several flows, the excavations have in some instances passed through the basalt disclosing gravels, sands, and sandy clays of probably fluviatile origin underneath. They apparently represent the old channel of the Yarra. In several places fragments and trunks of trees have been found lying embedded in these sediments. The wood of the trees was carbonised and in parts filled with pyrite. The basalt extends some miles further up the valley of the Yarra to Dight's Falls, and connects with the flow that came down Merri Creek, and the sheet that forms the gently sloping country from the Merri Creek to Alphington. In the City of Melbourne Corporation quarry, also, on the western bank of Merri Creek, at Clifton Hill, there is a thickness of about 100 feet of basalt. Trunks of small trees and pieces of wood, all carbonised, were found in the sediments underlying. The basalt in this quarry is exceptionally rich in zeolites, and various forms of carbonate of lime, and some dazzlingly beautiful specimens are from time to time revealed by the operations carried on. In one instance a small chamber in the basalt was broken into and found to be resplendent with innumerable clusters, bunches and single crystals.

Though in these quarries the basalt is so thick only one flow appears to have extended down as far as the Botanical Gardens and Queen's Bridge. In the former locality on its northern fringe it is covered by several feet of grey clay derived from the Silurian rocks. Thus in shafts at the corner of Jolimont Street and Jolimont Road there is a thickness of six feet of brown and grey plastic and sandy clays lying on the basalt; in Wellington Parade, opposite the East Melbourne Cricket Ground, 18 feet of clays on the basalt; while at the corner of Jolimont Road and

1 Proceedings of the Royal Society of Victoria, vol. xxiii., 1886.

Wellington Parade, 15 feet of clays lie on Silurian claystones. The basalt has not been pierced in any of the shafts hereabouts. In parts of Yarra Park the basalt is covered by only a few inches of sandy alluvium, and along the fringe of the river, basalt may be seen in several places running to the edge of the stream, though not visible in the bank.

From being only a few chains wide at each end of the area under review the basalt reached a width of about 30 chains in the middle. Whether the whole of this flow came down through the narrow neck east of the Cremorne Railway Bridge, or some of it over the low Silurian rise between East Richmond and the railway is not apparent.

The Silurian rocks form interesting sections near both entrances to the Botanical Gardens from the Yarra side, and also from the Old Pumping Station to near the Engineers' Depot. Here a fine section discloses what appears to be a local example of qua-quaversal dip, and two interesting dykes. These are quite distinct in character from each other. The more eastern one, which is about 3ft. 6in. wide, and bearing north and south obliquely across the beds, dips about W. at 60°. It is so decomposed that its original character is not detectable. It has the appearance, however, of having been of a mica felspathic nature, and black mica (biotite) is still visible though mostly decayed, giving the rock a rusty brown color. The beds on the foot wall are considerably crushed and twisted for a few feet back from the dyke. The other and much larger dyke has been intruded along the bedding plane of the strata, and stands out prominently in color from the containing beds. From a short distance it appears to be one of the beds themselves, but closely examined it is seen to have entangled in it two small blocks of the sediments which show in such a pronounced manner that there is no mistaking the fact. The dyke rock is a fine-grained white granular one of apparently quartz and some glassy felspar, the latter predominating.

The strata here dip generally S. 70° W. at angles varying from 53° to 58° to the west of the dome, and N. 35° E. at from 30° to 35° to the east of it. In the section near the western Yarra entrance to the Botanical Gardens the rocks dip from W. to S. 80° W. at from 29° to 39°, while at the eastern entrance the dips

are S. 70° E. to S. 85° E. at from 72° to 75°. The rocks are claystones, mudstones, and fine hard sandstones. Some of them contain casts of fossils in fair number though few of them are in even a fairly good state of preservation. Brachiopods, like Atrypa and Cephalopods as Orthoceras are rather plentiful, and there also occur a few Trilobites. One of the last named, Cyphaspis spryi, found by Mr. F. Spry has recently been described by Professor Gregory, D.Sc., F.G.S., before this Society.

Now, taking the Yarra Improvement sections, we have first that on the north side of the river. This cutting forms a slight curve with a length down the middle from stream to stream of about 14 chains. On the occasions of all my visits basalt was noticeable on the north side only, and that, some distance away from the western end of the cutting. This western portion consisted solely of dark alluvium with remains of vegetable matter such as roots of reeds, etc., in the upper portions, merging into bluish-black marl in the lower, with a few shells in the layer on the floor of the cutting. About 60 yards from the western end of the section, commencing at the top, was basalt—thickness not ascertainable; dark alluvium with roots, 12 feet; bluish-black marl with few shells about 3 feet. There is no evidence to show the relation of the basalt to the shelly marl, though, at first sight, it appears to be overlying the sediments. It may be mentioned, however, that all my visits here were after the cutting had advanced past this point, and the slope had been trimmed and covered with material from the floor of the cutting, therefore, no good opportunity was afforded of satisfactory observation. Neither have I as yet been able to obtain any reliable information on the matter from those engaged on the work.

Taking a section near the east end (see Section A), the following, in descending order, were seen: greyish alluvium, getting gradually thicker as followed northwards, 3 feet 6 inches to 5 feet 6 inches; whitish alluvium, with fragments of roots, 3 feet 2 inches; black fissile clay, with three thin laminae of comminuted shells and lenticles of pure sand, 3 feet to 4 feet 6 inches; greenish-grey clay, the upper portions being intersected by numerous little cylindrical bodies consisting of the overlying black fissile clay, 1 foot; reddish-yellow sandy clay with greyish-white streaks from top of stratum to some distance into it, 5 feet

to 7 feet; vesicular and amygdaloidal basalt, much decomposed, 8 to 12 feet, not penetrated in the floor of the cutting. The shells in the black clay were apparently all of lamellibranchs, but were so much broken up that those sufficiently preserved to allow of a hope of identification were very few. A small collection of the material was made from several portions, but it has unfor tunately been mislaid. I regard this bed, however, as distinct from the shelly marl, and it directly overlies the basalt in one place. It may be the littoral portion of the estuarine deposit of which the shelly marl forms that laid down in deeper water. The greenish-grey clay extends only partly across the cutting, and the cylindrical bodies in it were probably worm burrows which were filled up with the overlying material.

In a section right at the end of the cutting (Section B), and about 4 feet from the river's edge, the strata showed as alluvium 2 to 3 feet; black fissile clay with fragments of the same kinds of shells as in the preceding section, not in distinct layers, but distributed through the clay except at the south end where they occur as a distinct layer lying on the sandy clay, 5 feet; yellowish sandy clay, 10 feet thinning to 5 feet going south; ferruginous quartz grit, 9 inches; ferruginous cemented conglomerate containing pebbles of quartz, sandstones, shales and basalt, 4 inches to 1ft. 6in.; basalt varying from 5 feet to 10ft. 6in., thinning towards the south. The conglomerate occurs as patches or thin bands and lies in eroded hollows of the basalt.

A small bed, 6 inches thick, of clayey gravel of quartz, shales and sandstones underlying bluish-black clay occurred about 50 yards from the east end of the cutting. It was 2 feet above the floor of the cutting and on the river (south) side of it.

From these sections it will be noticed that the shelly marl does not show in this north cutting for more than half way from the western end and it appears to trend in an oblique (S.E.) direction across it. This points towards the assumption that the cutting at its eastern end runs through the margin of the old estuary.

South of the Yarra the cutting was made through the corner of the Botanical Gardens and extended across the foot of Anderson Street until it met the river again 6 chains to the east. No basalt was met with in any part of this cutting, though

according to Mr. Catani, Engineer for Roads and Bridges in the Department of Public Works, basalt "boulders" were found in the cutting on the east side of Anderson Street.

In the western portion (Section C), the deposits were alluvium for varying thicknesses up to 7 feet; bluish-yellow and dark grey sandy clays and fine sand, 4ft. 6in. to 5ft.; dark bluish-grey clay with roots, 4 feet to 6ft. 6in.; bluish-grey marl with thin sandy layers and containing shells, 4 feet and upwards. The shells in this south cutting are not in such quantity, though in greater number of species than in the north cutting.

It may be mentioned, however, that a larger collection of shells was made in this cutting than in the other, which probably accounts for the fewer species recorded from the latter.

The following is the list of shells obtained, and I am indebted to Mr. J. H. Gatliff for kindly naming them:

Lamellibranchiata.	Gastropoda.
Chione sp.	Nassa pauperata (Lamarck).
Mytilus sp.	*N. labecula (A. Adams).
*Mactra sp.	*Cyclostrema micans (A. Adams).
Ostrea? juv.	= Liotia angasi (Crosse).
*Tellina deltoidalis (Lamarck).	*Natica plumbea (Lamarck).
Cardium tenuicostatum (Lamarck).	
Barnea australasiae (Gray).	Crustacea.
Venus laevigata (Sowerby).	
*Arca trapezia (Deshayes).	*Balanus (?) sp.

Note.—Those marked with an asterisk are from the north cutting only, the whole of them being found in the south cutting.

The shells occurring in profusion in the Botanical Gardens were Nassa, both species, and Tellina deltoidalis. Arca trapezia was scarce, while in the north cutting it was fairly plentiful. Natica plumbea was in fair number in both.

The eastern end of the cutting passed through the point of Silurian which had diverted the river a little to the N.W., and exposed an interesting section on the north side of the cutting. Here, at normal water level, may be seen the remnant of a 5 inch layer of brecciated conglomerate resting on the Silurian.

The lower portion consists of flattened, rounded and subangular pebbles of the local mudstones, claystones and sandstones; the upper portion of rounded pebbles of these rocks and of quartz in addition. All these pebbles are cemented together by slightly ferruginous sand. Overlying these are yellow, red, and white mottled fine sandy clays or clayey sands. This conglomerate is undoubtedly of local origin and derived from the Silurian rocks, while that in the east end of the north cutting is also local, but derived from both Silurian and basalt, thus, apparently, showing that the stream which made the pebbles ran between these two points over the contact of these two rocks, and, therefore, along about the same course as the present Yarra. The single outcrop of basalt south of the river occurs a few yards north of the point where the conglomerate is visible, but its relation to this band cannot be seen owing to the debris from the Silurian rocks from the cutting that has been piled on to it.

After getting through this Silurian point into the river in the south cutting, work has been extended only a short distance further up stream by slicing a strip of the southern bank for about 100 feet back from the river. In this portion, where work has been suspended at the Punt Road foot bridge, the excavation is only about 12 feet deep. About 8 feet of the upper portion is simply ordinary alluvium, but 4 feet on the bottom contain a few large pieces of carbonised wood and other fragments of vegetation. No basalt or shell marl are visible here.

The recent deposits in the south cutting presented some rather interesting features. In the alluvium and marl there are numerous very thin layers or partings, varying from a thread to $\frac{1}{2}$ inch in thickness, having a pronounced dip, ranging from N. 60° W. to N. at from 7° to 9° 30′. These layers on being examined proved to be very fine white sand, the marl caking off in a clean manner when disturbed. Most of them had white exudations of salt and what appeared to be magnesium chloride and in several cases small fragments of barnacles were visible. Shells were sparingly interspersed through the lower portions of the marl and small patches of barnacles occurred. The changing dip of the beds on the north side of the south cutting seems to indicate that they were laid down over a small rise by a gentle current not strong enough to cut through them and cause current bedding.

In the floor of the cutting two small springs were throwing out fine black sand and colorless water having a strong smell of sulphuretted hydrogen. The bubbling of one spring was distinctly audible a few yards away. Down the face of the slope of the bank on the south side there was a considerable percolation of water highly charged with iron, which left yellow, red, and brown deposits of chloride and oxides of iron. This was also a noticeable feature in the cutting on the north side and the colorless water which occurred there also was asserted by the workmen to have a poisonous effect on any skin abrasion with which it came into contact. In the portion in the south cutting nearest the new bridge in Anderson Street, the shells occurred in a distinctly stratified bluish-grey micaceous clay containing remains of reeds, wood, and masses of black vegetable mould without shells, which crumbled to powder on rubbing when dry. The mica has probably been derived from some dyke containing that mineral. A dyke of a granitic nature must occur somewhere in the vicinity, as rock of that kind was noticed in the material used for making the embankment on the Botanical Gardens side of the cutting, and this material was said by one of the workmen to have come from about the southern abutment of the bridge.

The similarity of these mineral water exudations from the sides of the cuttings to those described by Mr. Lucas from the Fishermen's Bend cutting is very great, and it is also a noticeable fact that the upper portions of the deposits in both places contained no animal remains of any kind. The nodules, however, so prevalent in the West Melbourne estuarine deposits, were not noticed in these.

The occurrence of these shelly marls so far up such a narrow valley as this of the Yarra is a feature of especial interest, more so on account of the narrow entrance to it at Prince's Bridge. There seems little doubt that this estuarine deposit under alluvium, as in the locality under notice, extends over a considerable portion of South Melbourne, and that the old course of the Yarra was to the S.W. through what is now Albert Park Lake running into Port Phillip somewhere between Albert Park and St. Kilda Railway Stations.

On the evidence furnished by these Yarra sections it appears as if the estuarine deposits may be provisionally regarded as

extending little, if any, higher up the river than the east end of Anderson Street cutting.

The section in the north cutting shows apparently that the basalt margin occurs in the cutting not reaching the south side except at the south-east end, and that the shelly marls were deposited against its side. Over these the river brought down quantities of alluvium, which accounts for the absence of marine shells and presence of roots and vegetable matter. There does not appear to be any unconformity between the alluvium and the shelly marl, the latter grading off into alluvium as the land was gradually raised and brackish and fresh water took the place of salt water.

The age of the basalt is, however, still a moot point. If it be regarded as overlying the shelly marls then its age is much younger than generally supposed, and brings it nearly to recent times, since the shells found in the marl are identical with, or but very slightly different from, those now living in the Bay.

DESCRIPTION OF PLATES XLI. AND XLII.

PLATE XLI.

Geological map of the Yarra Valley near the Botanical Gardens, Melbourne.

PLATE XLII.

Geological sections to illustrate map.